EFFECT OF ZR02 AND AL203 FLUX COATING DURING TIG WELDING ON MS (AISI1010) AND SS (AISI 304)

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Abstract

The necessity of fabrication of large components makes joining processes inevitable in all industrial sectors. Welding is one of the most widely used manufacturing processes for joining similar and dissimilar metals. Of the many kinds of welding processes, tungsten inert gas (TIG) welding, also known as gas tungsten arc welding (GTAW) is highly popular owing to its many advantages such as a high level of process control and the ability to obtain cleaner welds. However, TIG welding is associated with an intrinsic drawback of low depth of penetration and it is hence a viable process for welding thin plates only. Welding thicker plates using TIG welding necessitates multi-pass welding and its concomitant demerits such as a larger heat-affected zone. Over time, many variants of TIG welding have been developed. Flux-assisted welding is one important class of recently developed variants in which an activating flux is used to modify the weld pool dynamics to achieve a greater depth-to-width ratio. This chapter discusses in detail the major flux-assisted TIG welding techniques, namely, activated TIG welding, flux zoned TIG welding, strengthening activated TIG welding and flux bounded TIG welding. Apart from these, other significant advancements such as the advanced activated TIG welding, keyhole TIG welding, Super-TIG welding, etc. are also investigated. Many of the modified TIG welding techniques are in the early stages of their research. Further studies will help mature the technologies used which will lead to wider commercialization and more applications of these processes.

Keywords:*(TIG)* tungsten inert gas*, (GTAW), face bound powder deposition.*

1. Introduction

Resistance welding is the most commonly used method for joining steel sheets. No filler metal is needed and the heat required for the weld pool is created by means of resistance when a high welding current is directed through the welded work pieces. An electro-conductive contact surface is created between the workpieces by pressing them together.

Contact is made using the shape of either the welded surfaces of the workpieces or the shape of the electrodes. Water-cooled electrodes made of alloyed copper are used in resistance welding. Electrodes convey a pressing force to the joint and direct the welding current to the joint in the appropriate manner. After welding, the electrodes rapidly cool down the welded joint. Work stages in resistance welding are very fast. The surfaces to be welded do not usually need to be cleaned before welding, in addition to which the weld does not usually require grinding or post heating. The resistance welding process can be easily automated. Resistance welding is a highly efficient production method that is particularly well-suited for automated production lines and mass production. Resistance welding is also suitable for small batch production, because the method is flexible, equipment simple and the welding process is easy to control.

2. Literature Review:

[1] **Touileb, Kamel & Djoudjou, Rachid & Ouis, Abousoufiane & Abdejlil, Hedhibi & Boubaker, Sahbi & Ahmed, Mohamed. (2023). Particle Swarm Method for Optimization of ATIG Welding Process to Joint Mild Steel to 316L Stainless Steel. Crystals. 13. 1377. 10.3390/cryst13091377**. 316L stainless steel joined to mild steel is widespread in several applications to reach a requested good association of mechanical properties at a lower cost. The activating tungsten inert gas (ATIG) weld was carried out using a modified flux composed of 76.63% SiO_2 + 13.37% Cr_2O_3+
10% NaF to meet standard recommendations in terms of limiting the root penetration. Modified optimal flux gave a depth of penetration 1.84 times greater than that of conventional tungsten inert gas (TIG) welds and a root penetration of up to 0.8 mm. The microstructure of the dissimilar joints was investigated using a scanning electron microscope and EDS analysis. The mechanical

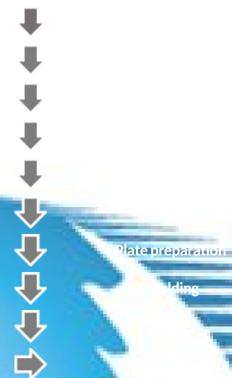
properties of the weld were not affected by the modified flux. The results show that the energy absorbed in the fusion zone in the case of ATIG weld (239 J/cm2) is greater than that of TIG weld (216 J/cm2). It was found that the weld bead obtained with the optimal flux combination in ATIG welding can better withstand sudden loads. The obtained UTS value (377 MPa) for ATIG welding was close to that of TIG welding (376 MPa). The average Vickers hardness readings for ATIG welds in the fusion zone are up to 277 HV, compared to 252 HV for conventional TIG welding.

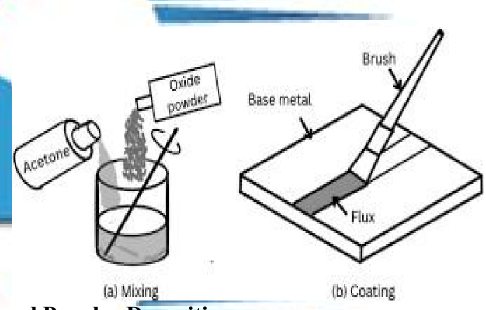
[1] **Cao, Fujun & Chen, Shujin & Du, Chengchao. (2018). Investigation of hot-wire TIG welding based on the heat-conduction. Energy Procedia. 144. 9-15. 10.1016/j.egypro.2018.06.003.** The hot-wire TIG welding equipment was built based on the heat-conduction method. The temperature-controlling model was developed and verified within a certain temperature range. The results showed that the wire temperature could be maintained at 220±5°C. The comparing experiments between the hot-wire TIG with a temperature of 220 °C and ordinary TIG were conducted. The results showed that the hot- wire TIG based on the heat-conduction method could improve the appearance and the feeding speed. When the appearance was similar, the efficiency of hot-wire TIG in root welding was doubled compared with that of the ordinary TIG. The efficiency of hot-wire TIG in cap welding was tripled compared with that of the ordinary TIG. Moreover, the microstructure of welding seam of the hot-wire TIG welding was finer than that of the ordinary TIG welding. The hardness of welding seam of the hot-wire TIG welding was harder than that of the ordinary TIG welding slightly. Good mechanical properties of the two joints have been indicated. The fracture was located in the ASTM A106 base metal.

N, Neethu & Goud Togita, Rahul & Patnaikuni, Neelima & Pammi, Chakravarthy & Svs, Narayana & Nair, Manoj. (2019). Effect of Nature of Flux and Flux Gap on the Depth-to-Width Ratio in Flux-Bounded TIG Welding of AA6061: Experiments and Numerical Simulations. Transactions of the Indian Institute of Metals. 72. 10.1007/s12666-019-01654-8. Flux-bounded tungsten inert gas welding is a variant of activated tungsten inert gas welding wherein activating flux is applied on the weld surface with a narrow flux gap along the line of weld. In this study, bead-on-plate welds were performed with flux gaps of 2, 3, 4, 5 and 6 mm

[2] using the fluxes silicon dioxide, titanium dioxide and calcium fluoride. The weld bead profiles were obtained using a stereomicroscope from which the depth-to-width ratios (DWRs) were calculated and compared with the DWR of a tungsten-inert-gas-welded plate. The reasons for differences in DWR were explained using the mechanisms involved and the captured images of the welding arc profile. The microstructure of the weld beads revealed no entrapment of flux particles. The increase in the DWR in the presence of activating flux was also substantiated using a numerical simulation model.

3. Methodology:





3.1 Face Bound Powder Deposition:

The plates were cleaned using a sharpening disc and cleaned with acetone to remove all oxides from the surface. Then the plates were coated on both sides of the welding line, this method is called Face bound (FB), which is recommended when welding aluminum sheets using the TIG . Figure shows the sample coated with zro2 and al203 Nanoparticles.

3.2 Tungsten inert gas welding process:

Electric discharge comprising of negatively charged electrons and positively charged ions. The arc converts the electric energy to heat energy which is subsequently used to melt the workpiece and to fuse them. Based on the polarities, welding is popularly performed in three modes

3.3 Mechanisms in FCTIG welding:

During FCTIG welding, the flux is coated with a narrow gap left in between. During welding, the edges of the flux coating come into contact with the welding arc leading to thermal dissociation. The surface active elements enter the weld pool and set up reverse convection currents providing a higher DOP and DWR. Since only a limited amount of flux enters the weld pool, it ensures that the optimum concentration to reverse the convection currents is achieved. The heat of the welding arc also forms the flux cloud which captures the weaker electrons and makes the welding arc narrower and denser. Apart from the reversal of convection currents and the arc root constriction effects which are active in ATIG/FZTIG welding as well, FCTIG welding also has an additional mechanism called 'insulation effect'. The combination of these three mechanisms improves the weld characteristics in FBTIG welding as compared to other conventional or flux-assisted TIG welding processes.

During welding, the parent metal melts by the bombardment of the charged species from the welding arc. The charged species will always choose the least resistant path for conduction. The common fluxes used are metal oxides or inorganic compounds that generally have higher electrical resistivity than the parent metal. During FBTIG welding, the welding arc will confine itself to the flux gap which is a more conductive path. This reduces the arc diameter making it denser resulting in a higher DOP

Tungsten inert gas welding is a versatile, reliant and popular welding technique. In general, a TIG welding system consists of a power source, a welding torch that contains the tungsten electrode, the shielding gas supply, the workpiece, and a filler rod if required. When TIG welding is performed without the addition of filler rods, it is called autogenous TIG welding. Figure 1 shows the schematic representation of a TIG welding system which can be performed manually or automatically. The major process parameters are welding current, welding voltage, arc travel speed, nature and flow rate of the shielding gas and filler wire feed rate.

In welding, a power source is specified by its current and voltage ratings. In manual TIG welding, a constant-current system, in which the amperage is maintained constant irrespective of the voltage is generally used. The power source can be either direct current (DC) or alternating current (AC). Using the power supply provided, a welding arc is struck between the tungsten electrode and the parent metal. The welding arc consists of an

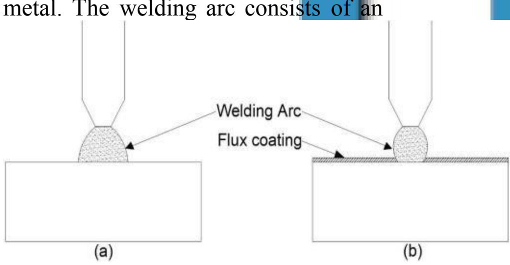


Figure : Schematics of the welding arc in (a) TIG welding, and (b) FCTIG welding.

4. Experimental procedure:

When choosing the filler metal, the corrosion stress has to be regarded, as well. The use of a higher alloyed filler metal can be necessary due to the cast structure of the weld metal. A preheating is not necessary for this steel. A heat treatment after welding is normally is normally not usual. Austenitic steels only have 30% of

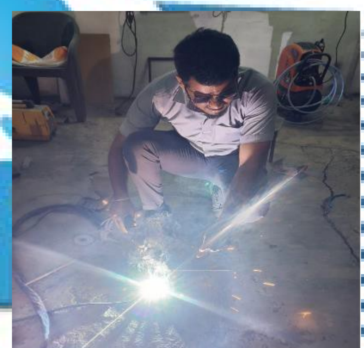


Fig: fc Tig welding

the thermal conductivity of non-alloyed steels. Their fusion point is lower than that of non-alloyed steel therefore austenitic steels have to be welded with lower heat input than non-alloyed steels. To avoid overheating or burn-though of thinner sheets, higher welding speed has to be applied. Copper back-up plates for faster heat rejection conductivity a greater distortion has to be expected. When welding 1.4404 all procedures, which work against this distrotion (eg. back-step sequence welding, welding alternately on opposite sides with double-V butt weld, assignment of two welders when the components are accordingly large) have to be respected notably. For produc thicknesses over 12mm the double-V butt weld has to be preferred instead of a single-V butt weld. The included angle should be 60° - 70°, when using TIG-welding about 50° are enough. An accumulation of weld seams should be avoided. Tack welds have to be afficed with relatively shorter distances from each other (significantly shorter than those of on- alloyed steels), in order to prevent strong deformation, shrinking, or flaking tak welds. the tacks shoudl be subsequently grinded or at least be free from crater cracks. 1.4404 in connection with austenitic weld metal and too high heat input the addiction to form heat cracks exists. the addiction to heat cracks can be confined, if the weld metal features a low content of ferrite (delta ferrite). Contents of ferrite up to 10% have a favorable effect and do not affect the corrosion resistance generally. The thinnest layer as possible have to be welded (stringer bead technique) because a higher cooling speed decreases the addition to hot cracks. A

preferably fast cooling has to be aspired while welding as well, to avoid the vulnerability to intergranular corrosion and embrittlement. 1.4404 is very suitable for laser beam welding (weldability A in accordance with DVS bulletin 3203, part 3) Witha welding groove width smaller 0.3mm respectively 0.1mm product thickness the use of filler metals is not necessary.

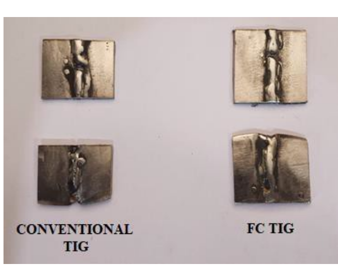
4.1 Welding parameters:

Parameters	Range
Welding speed	13 cm/min
Welding current	150 Amp
Arc Length	2 mm
Electrode tip angle	45°
Shielding gas on the workpiece	Argon with flow rate 10 L/min
Shielding gas on the backside	Argon with flow rate 5 L/min
Welding mode	Negative direct current electrode

5.Testing and results:

A collateral effect of increased rate of heat input per unit length of weld bead is the unimpeded conduction of heat in lateral direction of the metallic base plates. While heat penetration in vertically downward direction is advantageous (as it enhances penetration), the heat fow in lateral direction is detrimental as it increases the weld bead width. It can also undesirably increase the heat affected zone (HAZ) and lead to severe microstructural damage surrounding the joint. The increasing nature of weld bead width with current can also be clearly observed from Fig. for TIG and all cases of FA-TIG welding. Frequent catastrophic breakage of the refractory cap located at the tip of TIG welding torch is also observed at higher heat input. This increased tendency of breakage can be attributed to the forehand welding technique where the torch exists just above the deposited puddle, and thus, the refractory cap continuously experiences heat. At higher current, the ceramic cap is incessantly exposed to hotter puddle leading to random breakage. In this investigation, the fller metal deposition rate is kept invariable across all the trials. Accordingly, a simultaneous increase in both penetration and weld bead width results in gradual drop in reinforcement (R) as the volume of filler metal deposited per unit length of the weld bead is unchanged. This gradual descending tendency of reinforcement with increase

in current can be observed in Fig



5.1The geometric dimensions of the weld metal of the samples in different fluxes:

Sample	Depth of penetration (mm)	Bead width (mm)	D/W	Weld metal area (mm^2)
FCTIG	2.58 ± 0.55	9.91 ± 0.62	0.25 ± 0.02	19.6 ± 2.41
FCTIG	1.4 ± 0.29	4.06 ± 0.3	0.28 ± 0.01	4.48 ± 0.68
FCTIG	2.27 ± 0.15	5.33 ± 0.16	0.42 ± 0.01	9 ± 0.92
FCTIG	4.91 ± 0.28	6.33 ± 0.27	0.77 ± 0.02	18.05 ± 2.66
FCTIG	5.55 ± 0.23	7.4 ± 0.36	0.75 ± 0.01	28 ± 3.21
FCTIG	6 ± 0.12	5.93 ± 0.7	1.01 ± 0.08	29.2 ± 3.03
TIG	1.33 ± 0.1	4.92 ± 0.56	0.27 ± 0.01	6.06 ± 0.74
TIG	1.87 ± 0.32	6.71 ± 0.26	0.28 ± 0.03	8.34 ± 0.89
TIG	3.1 ± 0.52	9.68 ± 0.72	0.31 ± 0.03	19.54 ± 2.76

5.2 Mechanical properties of the welds:

SAMPLE	AVERAGE TENSILE STRENGTH (MPA)	FAILURE LOCATION
FCTIG	620 ± 3	–
CTIG	550 ± 7	Welded zone
FCTIG	600 ± 5	Welded zone
CTIG	580 ± 7	Welded zone
FCTIG	630 ± 4	Base metal zone

Conclusion:

This research focused on investigating the effect of two-component fluxes on melting efficiency through both experimental and analytical approaches, as well as on the resulting microstructure and mechanical properties in FCTIG welding of 316L stainless steel. The findings from this study are as follows.

- The dimensionless parameters previously used in conventional TIG welding, can also be applied in FCTIG welding.
- It has been shown that the calculation of dimensionless parameters (analytical approach) yields higher values than the measured values (experimental approach) for determining melting efficiency, with the measured values corresponding to the actual melting efficiency.
- The two-component fluxes used result in an increase in absorbed energy, which in turn increases the area of the weld metal and the melting efficiency.
- By modifying the flux composition and adding 20% OXIDE flux, compared to other studies with similar welding parameters, a 17% increase in penetration depth has been achieved with 20% less current intensity.

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References:

- Bîrdeanu, Aurel-Valentin, Cristian Ciucă, and Alexandru Puicea. 2012. "Pulsed LASER-(micro) TIG hybrid welding: Process characteristics." Journal of Materials Processing Technology 212, no. 4: 890-902. https://doi.org/10.1016/j.jmatprotec.2011.11.014.
- Cao, Fujun, Shujin Chen, and Chengchao Du. 2018. "Investigation of hot-wire TIG welding based on the heat- conduction." Energy Procedia 144:9-15.
- https://doi.org/10.1016/j.egypro.2018.06.003.
- Cary, Howard B., and Scott C. Helzer. 2005. Modern Welding Technology. New Jersey: Pearson Education.
- Chakravarthy, P., M. Agilan and N. Neethu. 2019. Flux Bounded Tungsten Inert Gas Welding Process: An Introduction. Boca Raton: CRC Press.
- Cui, Shuwan, Yonghua Shi, Yanxin Cui, and Tao Zhu. 2018. "The impact toughness of novel keyhole TIG welded duplex stainless steel joints." Engineering Failure Analysis 94: 226-
- 231. https://doi.org/10.1016/j.engfailanal.2018.08.009.
- Fujii, H. 2005. "Mechanism of A-TIG and AA-TIG (advanced A-TIG)." Welding international 19, no. 12: 934-939. https://doi.org/10.1533/wint.2005.3520.
- Fujii, Hidetoshi, Toyoyuki Sato, Shanping Lu, and Kiyoshi Nogi. 2008. "Development of an advanced A- TIG (AA-TIG) welding method by control of Marangoni convection." Materials Science and Engineering: A 495, no. 1-2: 296-303.
- https://doi.org/10.1016/j.msea.2007.10.116.
- Ming, Gao, Zeng Xiaoyan, and Hu Qianwu. 2007. "Effects of gas shielding parameters on weld penetration of CO2 laser-TIG hybrid welding." Journal of Materials Processing Technology 184, no. 1-3: 177-183. https://doi.org/10.1016/j.jmatprotec.2006.11.019.